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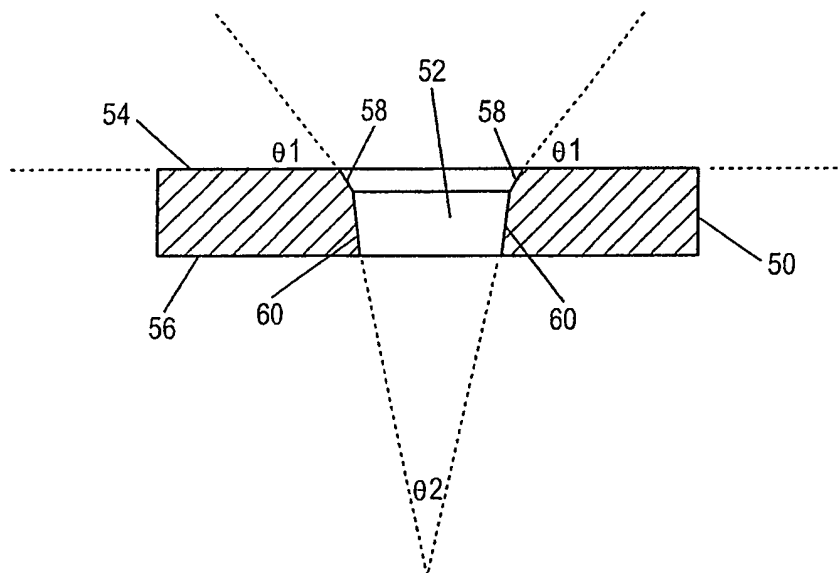
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(54) Title: BONE PLATES WITH HOLE FOR INTERCHANGEABLY RECEIVING LOCKING AND COMPRESSION  
SCREWS



(57) Abstract: Bone plates (50) with an upper surface (54), a bone contacting surface (56), and at least one hole (52) extending through the upper and bone contact surfaces (54, 56) are disclosed. A hole interchangeably accepts a compression screw for compression of a fracture and a locking screw that threads into the bone plate.

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**BONE PLATES WITH HOLE FOR INTERCHANGEABLY RECEIVING  
LOCKING AND COMPRESSION SCREWS**

This application claims priority to U.S. Application No. 10/673,833 entitled "Bone  
5 Plates and Bone Plate Assemblies," filed September 29, 2003, the entire contents of which  
are hereby incorporated by reference.

**Field of the Invention**

The invention relates generally to apparatuses for fixation of parts of a fractured  
bone, and, more particularly, to bone plates and bone plate assemblies, including bone  
10 plates and screws, for stabilization and compression of parts of a fractured bone.

**Background of the Invention**

Bone fractures lead to complex tissue injuries involving both the bone and the  
surrounding soft tissue. Treated in a conservative way, fractures often result in  
malalignment or non-unions and may also lead to stiffness of adjacent joints. To reduce  
15 the occurrence of these problems, open reduction and internal fixation of the bone can be  
carried out. Anatomical reduction and stable internal fixation with plates and screws are  
very successful in treating bone fractures.

Good bone healing can also result from relative stability, where the clinical  
outcome is often dependent on obtaining correct length, axis, and rotation of the fractured  
20 bone rather than on precise anatomical reduction and absolute stability. To achieve this,  
while at the same time minimizing the amount of additional soft tissue trauma, treatment  
of multi-fragmented metaphyseal and diaphyseal fractures with plates and screws was  
developed.

An existing solution is plate and screw systems where the screws are locked in the  
25 plate. The plate and screws form one stable system and the stability of the fracture is  
dependent upon the stiffness of the construct. No compression of the plate onto the bone  
is required, which reduces the risk of primary loss of reduction and preserves bone blood  
supply. Locking the screw into the plate to ensure angular, as well as axial, stability  
eliminates the possibility for the screw to toggle, slide, or be dislodged and thereby  
30 strongly reduces the risk of postoperative loss of reduction. As the relationship between  
the locking screws and the plate is fixed, locking screws provide a high resistance to shear

or torsional forces, but locking screws have a limited capability to compress bone fragments.

Furthermore, existing plates with openings that accept locking screws typically only accept certain screw sizes with specified types of screw heads. For example, an existing plate and screw system includes a lag screw with a shallow thread form and a conical screw head. This limits the angulation of the screw, and the thread form is not optimal for lagging bone pieces together. This may be limiting in certain cases, for example with a distal femur fracture where a surgeon desires to lag the condyles. Because such existing plates do not accept large screws with spherical screw heads, surgeons are limited to lagging fragments outside the plate or using screws which are poorly designed for this application.

Because of these shortcomings, many surgeons began expressing the desire to have plate and screw systems (or bone plate assemblies) where the surgeon can choose intraoperatively whether to use the bone plate with compression screws (also referred to as cortical or cancellous screws), locking screws, or with a combination of both. This led to the development of a combination slot, a compression slot combined with a partially threaded opening, that could receive either a compression screw or a locking screw.

Bone plate assemblies that combine compression screws and locking screws are ideal in certain clinical situations. Bone plates with combination slots, including partially threaded openings, are well known to those skilled in the art. The partially threaded portions allow either locking or compression screws to be used. Because the slots are only partially threaded, the locking screws may not be able to maintain the fixed angular relationship between the screws and plate under physiological loads. Specifically, the locking screws within the plate are only partially captured and thus only partially surrounded by threads. Under high stress and loading conditions, the slot may distort and allow the fixed angular relationship between the locking screw and plate to change. This can result in loss of fixation or loss of established intraoperative plate orientation. Because of the slot geometry, translation of the plate with compression screws may be limited to a single direction, which may be disadvantageous in reduction and manipulation of fragments.

Additionally, bone plates that allow for a surgeon to use provisional fixation techniques are also desirable. Provisional fixation of a bone plate to the bone allows the

surgeon to fix the plate to the bone without the use of clamps or similar tools. In this way, the surgeon may place the bone plate in the proper position before inserting all of the locking screws into the bone plate and bone, while at the same time keeping excess instruments, such as clamps, out of the field of view of the surgeon and allowing for  
5 higher quality x-rays of the bone and bone plate construct during surgery.

Accordingly, there is a need for improved bone plates that may be used with both compression and locking screws for improved stabilization and compression of parts of a fractured bone. There is also a need for improved bone plates with holes that may be used for locking a bone plate to the bone, but that also accept different size screws with varying  
10 types of screw heads. Finally, there is need for improved bone plates that accept provisional fixation pins through the holes of the plate.

### Summary of the Invention

The present invention provides bone plates and bone plate assemblies for stabilization and compression of parts of a fractured bone. According to an exemplary  
15 embodiment of the present invention, a bone plate includes an upper surface, a bone contacting surface, and at least one hole extending through the upper surface and the bone contacting surface that may interchangeably receive a locking screw and a compression screw, wherein each hole includes a thread that makes a complete revolution around the hole.

According to certain exemplary embodiments, each hole may include a top portion  
20 extending from the upper surface and a threaded bottom portion extending from the top portion to the bone contacting surface. The top portion of the hole may extend from the upper surface of the bone plate at a first angle relative to the plane of the upper surface. The top portion of the hole may include a ramp extending from the upper surface at a first  
25 angle relative to the plane of the upper surface and a concave recessed portion that is generally spherical. The first angle may be fifty-two degrees in either instance. The bottom portion of the hole may be generally cylindrical or tapered with an included angle of less than about thirty degrees. The included angle may be about twenty degrees. Each hole is configured to engage a head of a compression screw and provide compression of  
30 fractured bone fragments. Using a compression screw, fine adjustment of a fracture of up to two millimeters in more than one direction is possible. Each hole is configured to

threadably engage a head of a locking screw and fix the locking screw with respect to the bone plate.

In another exemplary embodiment, a bone plate includes an upper surface, a bone contacting surface, and at least one hole extending through the upper surface and the bone contacting surface that may interchangeably receive a locking screw and a compression screw, wherein each hole includes (a) a top portion extending from the upper surface and (b) a bottom portion extending from the top portion to the bone contacting surface, wherein the bottom portion is threaded to receive threads of a head of a locking screw and the bottom portion includes at least one thread that makes a complete revolution around the hole. In certain embodiments, the top portion extends from the upper surface at a first angle relative to the plane of the upper surface and the bottom portion is tapered with an included angle of less than about thirty degrees. The first angle may be about fifty-two degrees and the included angle may be about twenty degrees. In certain embodiments, the top portion includes a ramp extending from the upper surface at a first angle relative to the plane of the upper surface and a concave recessed portion that is generally spherical and the bottom portion is generally cylindrical.

In another exemplary embodiment according to this invention, a bone plate assembly includes a bone plate, at least one locking screw, and at least one compression screw. The bone plate includes an upper surface, a bone contacting surface, and at least one hole extending through the upper surface and the bone contacting surface that may interchangeably receive a locking screw and a compression screw, wherein each hole includes a thread that makes a complete revolution around the hole.

In certain exemplary embodiments of a bone plate assembly, a hole is configured to engage a head of the compression screw and provide compression of fractured bone fragments. Each hole may be configured to engage a head of the compression screw such that fine adjustment of a fracture of up to two millimeters in more than one direction is possible and to threadably engage a head of a locking screw and fix the locking screw with respect to the bone plate.

In certain exemplary embodiments of a bone plate assembly, a head of the locking screw may include threads that engage threads in the hole. Both the head of the locking screw and the hole may be tapered. The head of the locking screw and at least a portion of the hole may be tapered at an included angle of less than about thirty degrees. The

locking screw may include a head with triple lead threads and a single lead threaded shaft such that all threads of the locking screw are of a constant pitch. In certain embodiments, the lead of threads of the locking screw is not continuous between the threads of the head and the threads of the shaft of the locking screw. Each hole of the bone plate may include  
5 a top portion extending from the upper surface and a threaded bottom portion extending from the top portion to the bone contacting surface.

Certain exemplary embodiments of this invention also include methods of reducing a fracture.

According to the present invention, there is provided a bone plate having an upper  
10 surface and a bone contacting surface, characterized in that the bone plate comprises at least one hole extending through the upper surface and the bone contacting surface that may interchangeably receive a locking screw and a compression screw and including a thread that makes a complete revolution around the hole.

According to the present invention, there is provided a method for reducing a  
15 fracture of a bone characterized in that the method comprises (a) coupling a bone plate to the bone with a screw inserted through the bone plate and into engagement with the bone on a first side of the fracture; (b) inserting a compression screw through a hole in the bone plate and into engagement with the bone on an opposite side of the fracture to adjust the position of the bone and surrounding tissue, wherein the bone plate comprises an upper  
20 surface, a bone contacting surface, and a plurality of holes extending through the upper surface and the bone contacting surface that, each hole configured to interchangeably receive a locking screw and a compression screw and including a thread that makes a complete revolution around the hole; (c) removing the compression screw from the hole and engagement with the bone; and (d) inserting a locking screw into the hole and into  
25 engagement with the bone to fix the position of the bone plate, wherein threads of the hole completely surround threads of a head of the locking screw.

#### **Brief Description of the Drawings**

Figure 1A shows a side view of an exemplary locking screw according to one embodiment of the present invention.

30 Figure 1B shows a cross-sectional view of the locking screw of Fig. 1A.

Figure 2A shows a top view of a portion of a bone plate, including a hole without the threads of the hole shown, according to one embodiment of the present invention.

Figure 2B shows a cross-sectional view of the portion of the bone plate shown in Fig. 2A as viewed along cross-section lines 2B-2B of Fig. 2A.

Figure 2C shows a top view of the portion of the bone plate shown in Figs. 2A and 2B, with the threads of the hole shown.

5        Figure 2D shows a cross-sectional view of the portion of the bone plate shown in Figs. 2A-2C as viewed along cross-section lines 2D-2D of Fig. 2C.

Figure 2E shows a detailed view of the hole of the portion of the bone plate shown in Figs. 2A-2D.

10       Figure 3 shows a side view of the locking screw of Figs. 1A and 1B threaded into the portion of the bone plate shown in Figs. 2A-2E.

Figure 4 shows a side view of an exemplary compression screw for use according to one embodiment of the present invention.

Figure 5 shows a side view of the compression screw of Fig. 4 inserted into the portion of the bone plate shown in Figs. 2A-2E.

15       Figure 6A shows a side view of an exemplary locking screw according to an embodiment of the present invention.

Figure 6B shows a cross-sectional view of the locking screw of Fig. 6A.

Figure 7A shows a top view of a portion of a bone plate according to an embodiment of the present invention.

20       Figure 7B shows a cross-sectional view of the portion of the bone plate shown in Fig. 7A as viewed along cross-section lines 7B-7B of Fig. 7A.

Figure 7C shows a detailed view of the hole of the portion of the bone plate shown in Figs. 7A and 7B.

25       Figure 8 shows a side view of the locking screw of Figs. 6A and 6B threaded into the portion of the bone plate shown in Figs. 7A-7C.

Figure 9 shows a side view of the compression screw of Fig. 4 inserted into the portion of the bone plate shown in Figs. 7A-7C.

Figures 10-27 are perspective views of various exemplary bone plate configurations according to various embodiments of the present invention.

30       Figure 28 shows a provisional fixation slot according to one embodiment of the present invention.

Figures 29-33 are perspective views of various exemplary bone plate configurations according to various embodiments of the present invention.

### **Detailed Description of the Invention**

The present invention provides bone plates and bone plate assemblies for stabilization and compression of parts of a fractured bone. According to certain exemplary embodiments of this invention, a bone plate includes an upper surface, a bone contacting surface, and at least one hole extending through the upper surface and the bone contacting surface that may interchangeably receive a locking screw and a compression screw. The bone plate may include additional openings that receive only compression screws or only locking screws. The bone plate may also include pinholes that accept provisional fixation pins, but that are not large enough to receive bone screws.

A threaded head of an exemplary locking screw for use in accordance with this invention is received by threads in a corresponding hole such that the threads of the hole completely surround the threads of the head of the locking screw. This relationship between the head of the locking screw and the threads of the hole contributes to maintaining fixation of the bone plate and strengthening the plate and screw combination. As noted, a compression screw may also be received within the hole of the bone plate. As the compression screw is fully inserted within a bone, the head of the compression screw comes into contact with and rides along a top portion of the hole, allowing for fine adjustment of the position of the bone plate in more than one direction.

Figures 1A and 1B show an exemplary locking screw for use according to one embodiment of the present invention. A locking screw 40 includes a threaded head 42 and a threaded shaft 44. Locking screw 40 may be a 3.5 mm, 4.5 mm, 6.5 mm, or other size locking screw, which is understood by those skilled in the art. In the exemplary embodiment shown in Figs. 1A and 1B, the lead between the threads of head 42 and the threads of shaft 44 is broken. The threads in shaft 44 of locking screw 40 are single lead and the threads in head 42 are triple lead, providing locking screw 40 with same pitch throughout. It is preferable for certain embodiments of locking screws according to this invention to have a constant pitch. In an exemplary 3.5 mm locking screw, the pitch is 1.25 mm and the angle of the thread form is about 45 to about 60 degrees. In an exemplary 4.5 mm locking screw, the pitch is 1.75 mm and the angle of the thread form is



about 60 degrees. Locking screw 40 also includes an internal hex head 46, as shown in Fig. 1B, that is used when tightening locking screw 40 into a bone plate and/or bone.

Figures 2A-2E show different views of a portion of a bone plate according to an embodiment of the present invention. For ease of illustration and for purposes of describing an exemplary embodiment of the present invention, only a portion of bone plate 50 is shown in Figs. 2A-2E. Bone plates generally include one or more holes or other openings, including pinholes that cannot receive bone screws, such as in the exemplary bone plates shown in Figures 10-27 and 29-33, which are briefly described below. For example, the bone plates shown in Figs. 27 and 29-33 include only holes of the type described herein that may receive either locking screws or compression screws interchangeably. These bone plates also include non-threaded pinholes that may receive provisional fixation pins, but that cannot receive bone screws. As other examples, the bone plates shown in Figs. 10-26 generally include holes of the type described herein that may receive either locking screws or compression screws interchangeably, as well as other oblong or non-threaded openings for receiving bone screws. These bone plates may also include cross-shaped slots or pinholes for receiving provisional fixation pins as well.

The particular bone plate 50 shown in these drawings includes a hole 52 extending through an upper surface 54 and a bone contacting surface 56 of bone plate 50. Figs. 2A and 2B show hole 52 without its threads to help illustrate certain aspects of this embodiment of the invention, while Figs. 2C-2E show hole 52 with its threads. It should be understood that the geometry of hole 52 is the same throughout these drawings, although the geometry of hole 52 is not as clearly visible in the drawings that show the threads of hole 52. As seen most clearly in Fig. 2B, hole 52 includes a top portion 58 extending downward from upper surface 54. Top portion 58 extends from upper surface 54 at an angle of  $\theta_1$  relative to the plane of top surface 54, as shown in Fig. 2B. In an exemplary embodiment, angle  $\theta_1$  is about fifty-two degrees.

A bottom portion 60 of hole 52 extends from the end of top portion 58 through bone contacting surface 56 of bone plate 50. Bottom portion 60 includes threads 62, as shown in Figs. 2C-2E. Some of threads 62 may extend into top portion 58 depending on the particular embodiment, but top portion 58 is not completely threaded.

In the exemplary embodiment shown in Figs. 2A-2E, bottom portion 60 is tapered. The included angle,  $\theta_2$  shown in Fig. 2B, of the taper of bottom portion 60 may be less

than about thirty degrees, including zero degrees (i.e., no taper at all). The larger the included angle, the larger hole 52 in bone plate 50 must be, which begins to compromise the strength of the plate if the included angle is much larger than about thirty degrees. In an exemplary embodiment,  $\theta_2$  is about twenty degrees.

5        Figure 3 shows a side view of locking screw 40 threaded into hole 52 of bone plate 50. Head 42 of locking screw 40 is received by threads 62 of bone plate 50. Threads 62 completely surround the threads of head 42, and the top of head 42 is received completely within hole 52 such that head 42 of locking screw 40 sits flush with upper surface 54 of bone plate 50. Shaft 44 of locking screw 40 is threaded into bone (not shown). Head 42  
10 of locking screw 40 should be tapered such that it properly mates with threads 62 of hole 52 of bone plate 50. Furthermore, a threaded portion of a head of a locking screw for use with certain embodiments of this invention should have a taper generally corresponding to the taper, if any, of the threads of the hole of the bone plate.

Figure 4 shows a side view of an exemplary compression screw for use according  
15 to an embodiment of the present invention. A compression screw 70 includes a head 72 and a threaded shaft 74. Figure 5 shows compression screw 70 inserted within hole 52 of bone plate 50. As shown in Fig. 5, head 72 of compression screw 70 rides along top portion 58 of bone plate 50. As shaft 74 is threaded into a bone (not shown), compression screw 70 may pull or push bone plate 50 in a particular direction as head 72 of  
20 compression screw 70 comes into contact with and rides along top portion 58 of hole 52 of bone plate 50. The angle  $\theta_1$ , shown in Fig. 2B, at top portion 58 of hole 52 is significant for compression of a fracture and is necessary to help shift the bone plate in the desired direction. If top portion 58 were to extend straight down from upper surface 54 of bone plate 50, compression would be less successful. Compression screw 70 may move  
25 bone plate 50 in more than one direction as compression screw 70 is fully inserted within hole 52. In an exemplary embodiment, fine adjustment of fractures up to about two millimeters in several directions is possible.

Figures 6A and 6B show another exemplary locking screw for use according to an embodiment of the present invention. A locking screw 80 includes a head 82 and a  
30 threaded shaft 84. Similar to locking screw 40 shown in Figs. 1A and 1B, locking screw 80 may be a 3.5 mm, 4.5 mm, 6.5 mm, or other size locking screw, which is understood by those skilled in the art, and the lead between the threads of head 82 and the threads of

shaft 84 is broken. The threads in shaft 84 of locking screw 80 are single lead and the threads in head 82 are triple lead, providing locking screw 80 with the same pitch throughout. The pitches and angles of thread form for exemplary 3.5 and 4.5 mm locking screws 80 are generally similar to those described above with reference to locking screw 5 40.

Locking screw 80 also includes an internal hex head 86, as shown in Fig. 6B, that is used when tightening locking screw 80 into a bone plate and/or bone. As may be seen from Figs. 1A, 1B, 6A, and 6B, only a portion of head 82 of locking screw 80 is threaded, whereas the entire head 42 of locking screw 40 is threaded. Additionally, the threaded 10 portion of head 82 of locking screw 80 is not tapered, while head 42 of locking screw 40 is tapered. These differences are because locking screw 40 is designed to mate with hole 52 of bone plate 50, while locking screw 80 is designed to mate with a hole 92 of a bone plate 90, as further described below.

Figures 7A-7C show different views of a portion of a bone plate according to an 15 embodiment of the present invention. As noted above, bone plates generally include one or more holes or other openings, such as in the exemplary bone plates shown in Figures 10-27 and 29-33, but for ease of illustration, only a portion of bone plate 90 is shown in Figs. 7A-7C.

Bone plate 90 includes a hole 92 extending through an upper surface 94 and a bone 20 contacting surface 96 of bone plate 90. Hole 92 includes a top portion 98 extending downward from upper surface 94. As shown in Fig. 7B, one side of top portion 98 includes a ramp that extends from upper surface 94 at an angle of  $\theta 3$  relative to the plane of top surface 94. In an exemplary embodiment, angle  $\theta 3$  is about fifty-two degrees. The remainder of top portion 98 is a concave recessed portion that is generally spherical in 25 shape, as shown in Fig. 7B.

A bottom portion 100 of hole 92 extends from the end of top portion 98 through bone contacting surface 96 of bone plate 90. Bottom portion 100 includes threads 102. Some of threads 102 may extend into top portion 98 depending on the particular embodiment, but top portion 98 generally has only the beginning of thread leads, if any 30 threading. Bottom portion 100 is not tapered, but rather is generally cylindrical in shape. In certain embodiments, for example, bottom portion 60 of hole 52 of bone plate 50, bottom portion 100 may be tapered at an included angle of less than about thirty degrees.

Figure 8 shows a side view of locking screw 80 threaded into hole 92 of bone plate 90. Threads of head 92 of locking screw 90 are received by threads 102 of bone plate 90. Threads 102 completely surround the threads of head 92, and shaft 84 of locking screw 80 is threaded into bone (not shown). Head 82 of locking screw 80 is shaped such that its  
5 unthreaded portion bears against the ramp of top portion 98 of hole 92 of bone plate 90. Additionally, the threaded portion of head 82 is generally cylindrical (i.e., not tapered) so that it properly mates with threads 102 of hole 92 of bone plate 90. A threaded portion of a head of a locking screw for use with certain embodiments of this invention should be shaped to generally correspond to the shape of threaded portion of the hole of the bone  
10 plate.

Figure 9 shows compression screw 70 inserted within hole 92 of bone plate 50. As shown in Fig. 9, head 72 of compression screw 70 sits within the concave recessed or spherical portion of top portion 98 of bone plate 90. Head 72 of compression screw 70 contacts the side of top portion 98 that includes the ramp, but head 72 does not completely  
15 abut the ramp of top portion 98. As shaft 74 is threaded into a bone (not shown), compression screw 70 may pull or push bone plate 90 in a particular direction as head 72 of compression screw 70 comes into contact with and rides along top portion 98 of hole 92 of bone plate 90, similar to that described above with reference to Fig. 5. The angle  $\theta_3$ , shown in Fig. 7B, at top portion 98 of hole 92 is significant for compression of a  
20 fracture and is necessary to help shift the bone plate in the desired direction. If top portion 98 were to extend straight down from upper surface 94 of bone plate 90, compression would be less successful. Compression screw 70 may move bone plate 90 in more than one direction as compression screw 70 is fully inserted within hole 92. In an exemplary embodiment, fine adjustment of fractures up to about two millimeters in  
25 several directions is possible.

Certain exemplary embodiments of bone plates according to this invention include holes, such as hole 52 or hole 92, that not only receive compression or locking screws interchangeably but also accept multiple types of compression screw heads with varying outer and inner diameters and thread forms. A compression screw can be placed through  
30 such holes and use for fixation, provided the minor diameter of the screw shank does not exceed the minor diameter of the hole. The diameter of the head of the compression screw should not be less than the minor diameter of the hole because the compression

screw would not then rest on any part of the bone plate as is necessary for fracture reduction.

In practice, a first screw may be initially inserted through a bone plate and into a bone on one side of a fracture and then a second screw is inserted through the bone plate on the opposite side of the fracture. In an exemplary embodiment of a method according to this invention, after the first screw is in place, a compression screw is inserted through a hole in the bone plate on a side of the fracture opposite the side of the first screw. The compression screw may be inserted through the hole and into the bone such that as the compression screw is fully inserted, the bone plate is drawn over to a desired position. By moving the bone plate, the tissue is being pulled together to reduce the fracture. Once the compression screw has been used to move the bone plate into the desired position, the compression screw may be removed from the bone and bone plate and a locking screw may be inserted through the hole in the bone plate and in the bone in the space formerly occupied by the compression screw. The locking screw can then be tightened to lock the plate into position. The replacement of the compression screw with the locking screw is not required, but a locking screw may provide more stability and rigid fixation than leaving the compression screw in place. In some modes of operation, a locking screw is placed directly in a locking hole without first inserting a compression screw in the hole. Certain embodiments of the invention contemplate using locking screws and compression screws in any order and in combination or not in combination with each other. As described above, certain embodiments of this invention provide for fine adjustment of fractures in more than one direction.

Figures 10-26 show various exemplary bone plate configurations that may include one or more holes, such as holes 52 and 92 described above, that are capable of interchangeably receiving compression screws and locking screws. The exemplary bone plates shown in Figs. 10-26 may also include other openings configured to receive only locking screws or only compression screws, which is well understood by those skilled in the art. The exemplary bone plates shown in Figs. 10-26 may also include pinholes or provisional fixation slots that may receive provisional fixation pins. All holes in the exemplary plates of Figs. 10-26 include threads (not shown), while the other generally non-circular openings in these plates may or may not include threads depending on the

purposes for which the opening is to be used. Pinholes and provisional fixation slots are not threaded.

Figure 10 shows a distal radius plate 105 that is applied on the volar aspect of the radius and used to treat fractures of the distal radius. Figure 11 shows a distal tibia plate 110 used to treat distal tibia fractures and contoured to match the anatomy of the medial distal tibia. Figure 12 shows a calcaneal plate 120 that is applied to the medial aspect of the calcaneus and used to treat calcaneal fractures. Figure 13 shows a distal tibia plate 130 used to treat distal tibia fractures and contoured to match the anatomy of the lateral anterior distal tibia. Figure 14 shows a multipurpose plate 140 used in conjunction with the calcaneal plate to fuse the talus to the calcaneus. Figure 15 depicts a distal fibula plate 150 used to treat distal fibula fractures from the lateral side of the bone. Figure 16 illustrates a bone plate 160 used to treat the medial distal humerus. Figure 17 shows a proximal humerus plate 170 contoured to match the anatomy of the lateral proximal humerus. Figure 18 illustrates a distal femur plate 180 contoured to treat fractures of the distal femur from the lateral side of the bone.

Figure 19 shows a 1/3 tubular straight bone plate 190 used to treat small bone fractures. Figure 20 depicts a proximal tibia plate 200 contoured to treat proximal tibia fractures from the medial side. Figure 21 shows a reconstruction plate 210. Figure 22 illustrates a small fragment straight plate 220, and figure 23 illustrates a large fragment bone plate 230. Figure 24 illustrates an olecranon plate 240 used to treat fractures of the proximal ulna. Figure 25 shows a distal humerus plate 250 contoured to match the anatomy of the lateral posterior distal humerus. Figure 26 depicts a distal humerus plate 260 contoured to match the anatomy of the lateral distal humerus.

Shown in some of the exemplary bone plates in Figs. 10-26 are provisional fixation slots, such as, for example, slots 280 in Figs. 10 and 11, according to one embodiment of the present invention. Figure 28 shows provisional fixation slot 280 in a portion of a bone plate 282. As is well known to those skilled in the art, provisional fixation pins are commonly used to provisionally affix a bone plate to the bone prior to installation of the bone plate with permanent attachment, such as bone screws. More detailed information regarding provisional fixation of a bone plate to a bone prior to permanent attachment of the plate to the bone is provided in U.S. Patent No. 5,676,667 to Hausman, issued October 14, 1997, and U.S. Patent No. 5,968,046 to Castleman, issued

October 19, 1999, each of which is incorporated herein by reference in its entirety. Existing provisional fixation slots typically allow only fixation of bone fragments and not any adjustability of the position of bone fragments. An embodiment of a provisional fixation slot of this invention allows articulation of bone fragments in up to six degrees of freedom to reduce the bone fracture. A bone fragment may be locked into a position and then incrementally repositioned to another temporary or permanent location. In Fig. 28, slot 280 has a cross or x shape, but the shape of slot 280 may vary according to the desired functionality and may include I, L, T, and other shape slots.

In practice, a bone plate may be placed on the bone and the plate may or may not be affixed to the bone utilizing bone screws and/or provisional fixation pins. When provisional fixation is desired, a provisional fixation pin may be inserted through a provisional fixation slot and driven into the target bone fragment. The fragment may be manipulated to reduce the fracture and draw the fragment to the plate. Once the bone fragment is in a desired position, the provisional fixation pin may be tightened until the pin locks into the plate. If further movement of the bone fragment is desired, a second provisional fixation pin may be inserted in the same provisional fixation slot in a space in the slot that is not occupied by the first pin. After insertion of the second pin, the first pin may be removed and the bone fragment may be manipulated with the second pin. Once a desired position of the bone fragment is reached, the second pin is locked into the bone plate. Standard devices well known to those skilled in the art, such as screws, pins, cables, and other devices, may be used to affix the bone to the bone plate. Once the construct is sufficiently stable, any provisional fixation pins in use may be removed from the bone.

Preferably, certain embodiments of bone plates according to this invention include an upper surface, a bone contacting surface, and a plurality of holes extending through the upper surface and the bone contacting surface. Each hole may interchangeably receive locking and compression screw and includes a thread that makes a complete revolution around the hole (exemplary embodiments of such holes are hole 52 and hole 92 described above), and no other non-threaded holes or openings for receiving bone screws are present in the plates. Certain embodiments may also include non-threaded pinholes that are not capable of receiving bone screws, but which may be used for provisional fixation with provisional fixation pins.

Several exemplary embodiments of such bone plates are shown in Figs. 27 and 29-33. For example, Figure 29 shows a distal femur plate 290 contoured to treat fractures of the distal femur from the lateral side of the bone. Each hole 292 may interchangeably receive locking and compression screw and includes a thread (not shown) that makes a complete revolution around the hole. Pinholes 294 are also included, but pinholes 294 are too small to receive bone screws, are not threaded, and are used for provisional fixation accomplished with provisional fixation pins. The plates shown in Figures 27 and 30-33 likewise have holes and pinholes like holes 292 and pinholes 294 described above. Figure 27 shows a proximal tibia plate 270 contoured to treat proximal tibia fractures from the medial side. Figure 30 shows an anterior lateral distal plate 300. Figure 31 shows a medial distal tibia plate 310. Figure 32 shows a calcaneal plate 320 that is applied to the medial aspect of the calcaneus and used to treat calcaneal fractures. Figure 33 shows a straight plate 330 used to treat small bone fractures. It should be understood that numerous other types or shapes of bone plates may be made such that every screw-receiving hole in the bone plate may interchangeably receive locking and compression screws and includes a thread that makes a complete revolution around the hole.

An exemplary embodiment of a method of fracture reduction utilizing provisional fixation pins through a screw-receiving hole of a bone plate is described below. Other exemplary embodiments of methods of fracture reduction using compression screws and/or locking screws, as well as, optionally, provisional fixation pins, were described above.

A fracture is reduced with conventional forceps, and a bone plate of appropriate size and shape is placed over the fracture site. The bone plate is temporarily secured to the bone using provisional fixation pins. In a bone plate such as those shown in Figs. 27 and 29-33 described above, provisional fixation pins may be used through either the pinholes or the screw-receiving holes of the bone plate. For example, a 2 mm diameter provisional fixation pin may be used through a pinhole, a 2.7 mm diameter provisional fixation pin may be used through a 3.5 mm screw-receiving hole, and a 3.5 mm diameter provisional fixation pin may be used through a 4.5 mm screw-receiving hole. In one embodiment, provisional fixation is accomplished through the screw-receiving holes only.

Once one or more provisional fixation pins are used through these holes to secure the bone plate to the bone temporarily, a hole is drilled in the bone through one of the



other screw-receiving holes of the bone plate. A locking or compression screw with an appropriate head diameter is then inserted into the bone for fixation or for lagging bone fragments to the plate. Provisional fixation provides for temporarily securing the bone plate to the bone before placing fixation screws through the bone plate, so that one can be  
5 certain the bone plate is properly positioned before placing bone screws for permanent fixation of the bone plate to the bone. Moreover, with provisional fixation, x-rays can be taken of the bone plate/construct without excess instruments in the field of view.

The foregoing description of exemplary embodiments of the invention has been presented only for the purposes of illustration and description and is not intended to be  
10 exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations are possible in light of the above disclosure. The embodiments were chosen and described in order to explain the principles of the invention and their practical application so as to enable others skilled in the art to make and utilize the invention and various embodiments and with various modifications as are suited to the particular use  
15 contemplated. Alternative embodiments will become apparent to those skilled in the art to which the present invention pertains without departing from its spirit and scope.

### Claims

What is claimed is:

1. A bone plate having an upper surface and a bone contacting surface, characterized in that the bone plate comprises at least one hole extending through the upper surface and the bone contacting surface that may interchangeably receive a locking screw and a compression screw and including a thread that makes a complete revolution around the hole.

2. A bone plate according to claim 1, further characterized in that each hole includes a top portion extending from the upper surface and a bottom portion extending from the top portion to the bone contacting surface, wherein the bottom portion is threaded.

3. A bone plate according to claim 2, further characterized in that the top portion extends from the upper surface at a first angle relative to the plane of the upper surface.

4. A bone plate according to claim 2, further characterized in that the top portion includes a ramp extending from the upper surface at a first angle relative to the plane of the upper surface and a concave recessed portion that is generally spherical.

5. A bone plate according to claims 3 or 4, further characterized in that the first angle is about fifty-two degrees.

6. A bone plate according to any of claims 1-5, further characterized in that the bottom portion is generally cylindrical.

7. A bone plate according to any of claims 1-5, further characterized in that the bottom portion is tapered with an included angle of less than about thirty degrees.

8. A bone plate according to any of claims 1-7, further characterized in that each hole is configured to engage a head of a compression screw and provide compression of fractured bone fragments.

9. A bone plate according to claim 8, further characterized in that each hole is configured to engage the head of the compression screw such that fine adjustment of a fracture of up to two millimeters in more than one direction is possible.

10. A bone plate according to any of claims 1-9, further characterized in that each hole is configured to threadably engage a head of a locking screw and fix the locking screw with respect to the bone plate.

11. A bone plate according to any of claims 1-10, further characterized in that all holes in the bone plate for receiving bone screws are of the same configuration.

12. A system for reducing a fracture characterized in that the system comprises at least one locking screw, at least one compression screw, and a bone plate according to any of claims 1-11.

13. A system according to claim 12, further characterized in that each locking screw includes a head with triple lead threads and a single lead threaded shaft such that all threads of the locking screw are of a substantially equivalent pitch.

14. A system according to claim 13, further characterized in that the lead is not continuous between the threads of the head and the threads of the shaft of the locking screw.

15. A system according to any of claims 12-14, further characterized in that the system comprises at least one provisional fixation pin.

16. A system according to claim 15, further characterized in that the at least one provisional fixation pin is configured for use in holes for receiving bone screws.

17. A method for reducing a fracture of a bone characterized in that the method comprises:

(a) coupling a bone plate to the bone with a screw inserted through the bone plate and into engagement with the bone on a first side of the fracture;

(b) inserting a compression screw through a hole in the bone plate and into engagement with the bone on an opposite side of the fracture to adjust the position of the bone and surrounding tissue, wherein the bone plate comprises an upper surface, a bone contacting surface, and a plurality of holes extending through the upper surface and the bone contacting surface that, each hole configured to interchangeably receive a locking screw and a compression screw and including a thread that makes a complete revolution around the hole;

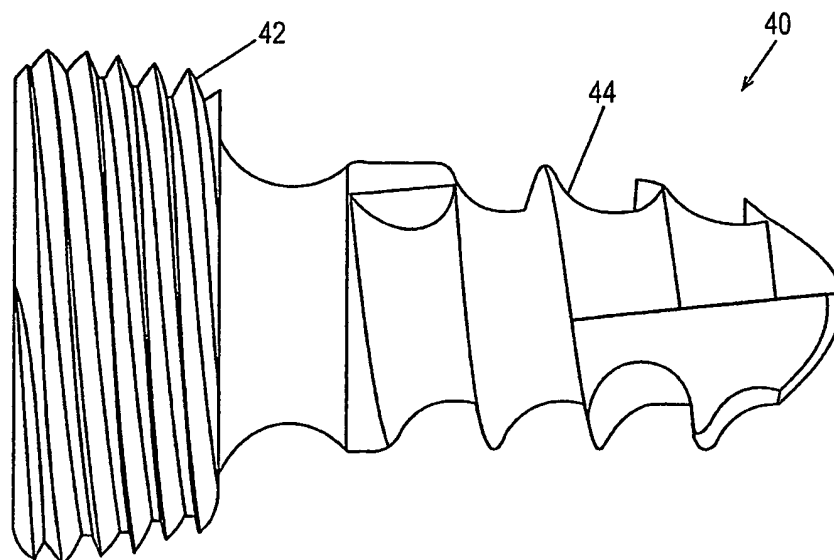
(c) removing the compression screw from the hole and engagement with the bone; and

(d) inserting a locking screw into the hole and into engagement with the bone to fix the position of the bone plate, wherein threads of the hole completely surround threads of a head of the locking screw.

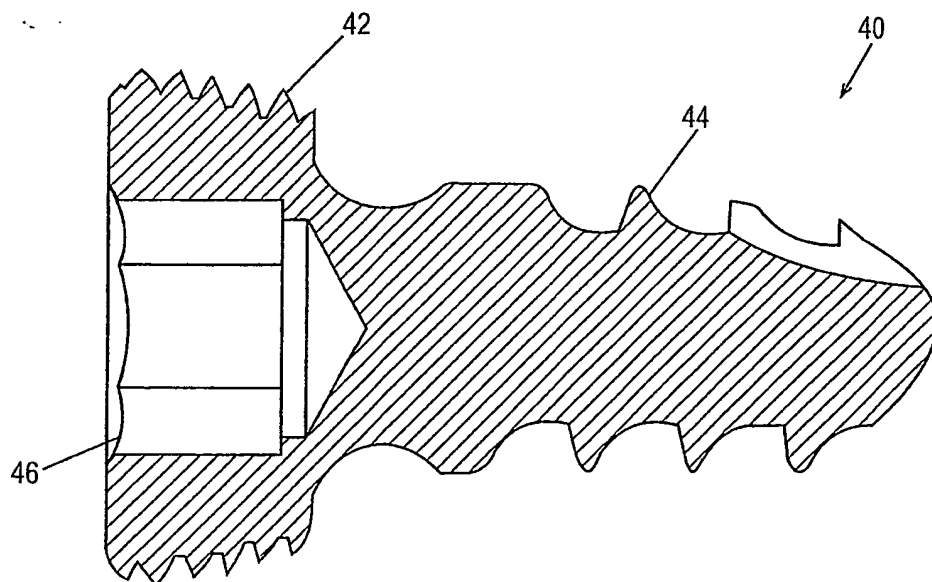
18. A method according to claim 17, further characterized in that the position of the bone and surrounding tissue may be adjusted by insertion of the compression screw up to two millimeters in more than one direction. -

19. A method according to claim 17, further characterized in that, prior to step (a), the method includes inserting one or more provisional fixation pins through one or more of the plurality of holes in the bone plate for receiving bone screws.

1/17

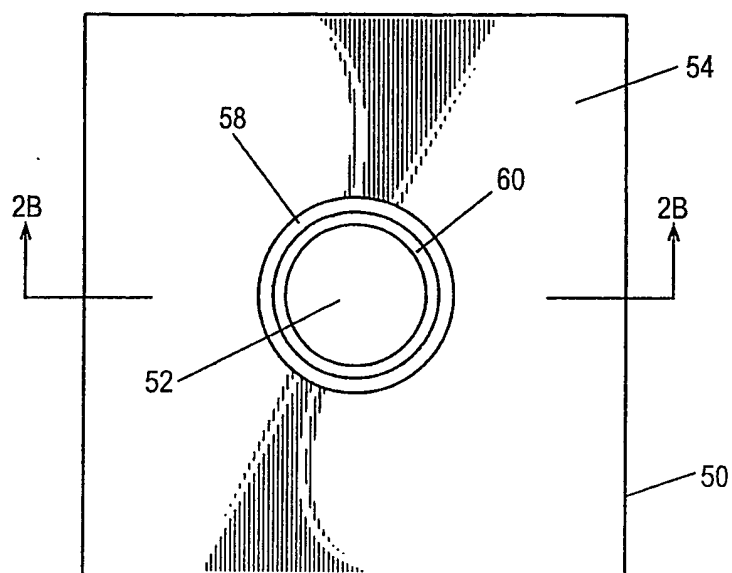
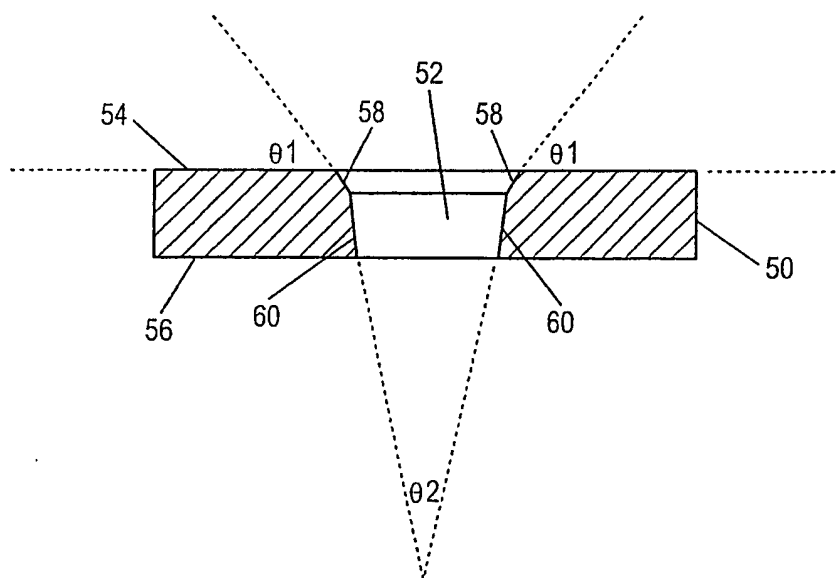


*Fig. 1A*

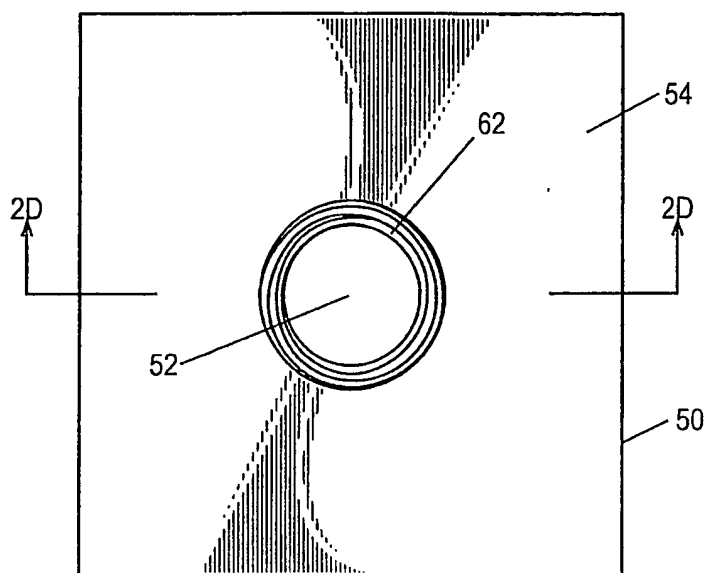


*Fig. 1B*

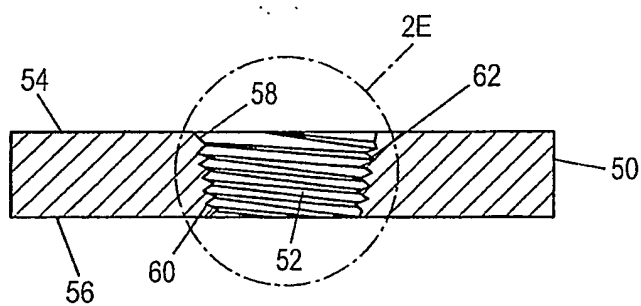
2/17

*Fig. 2A**Fig. 2B*

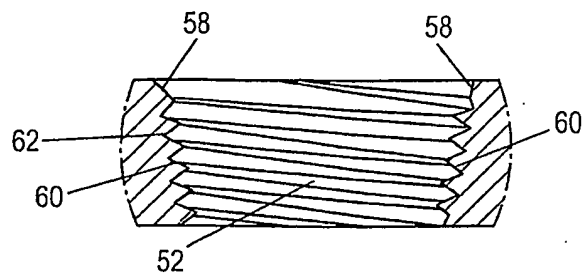
3/17



*Fig. 2C*

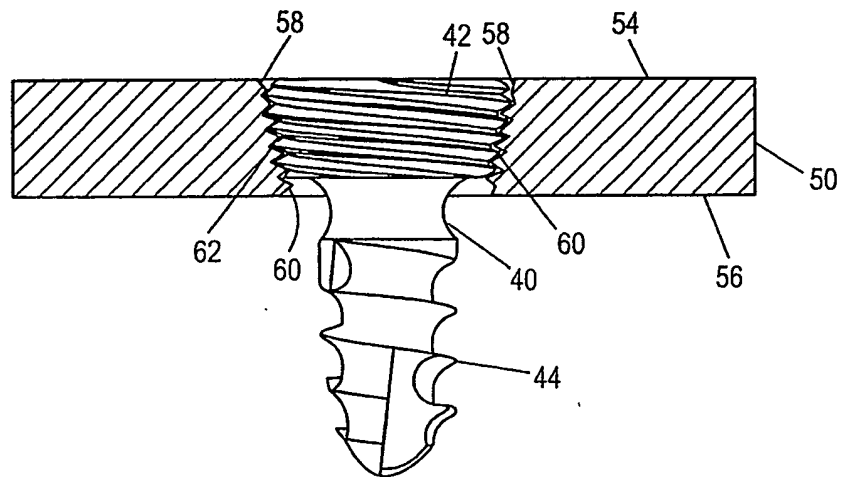


*Fig. 2D*

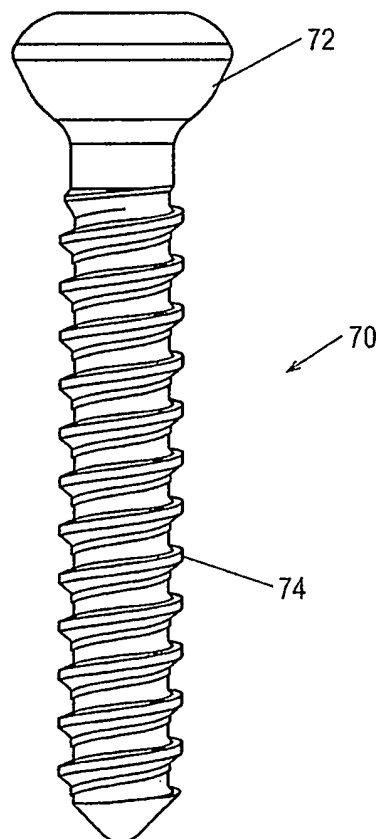


*Fig. 2E*

4/17

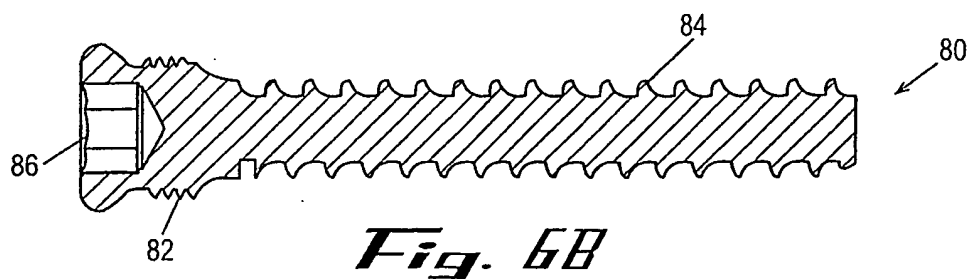
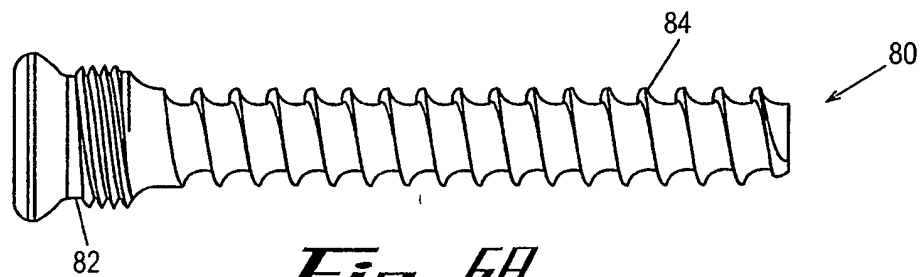
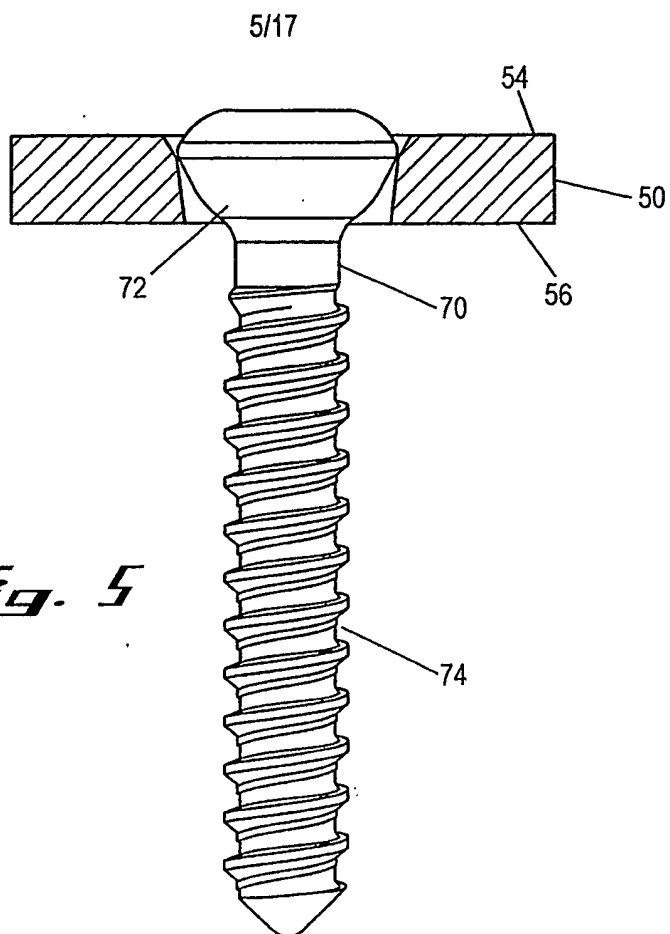


*Fig. 3*

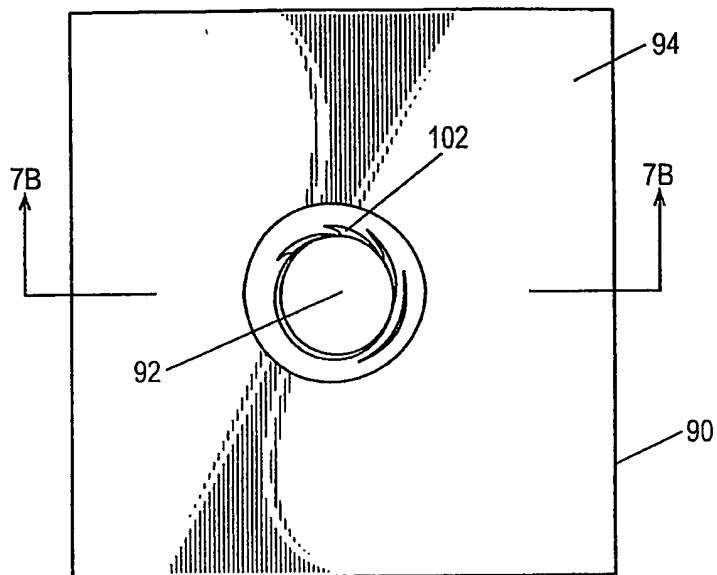


*Fig. 4*

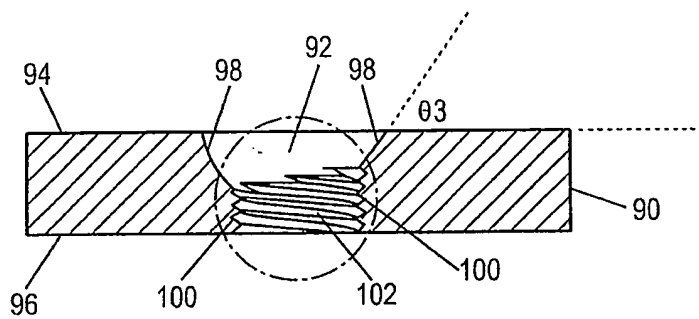




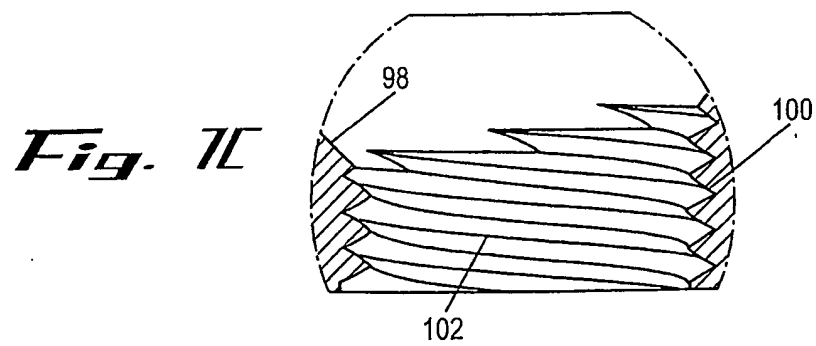
6/17



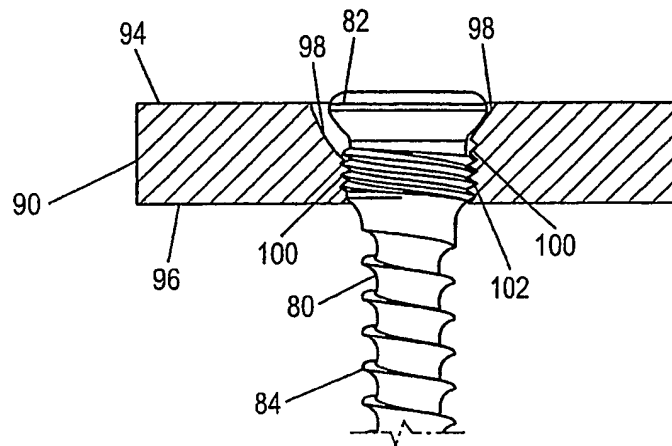
*Fig. 7A*



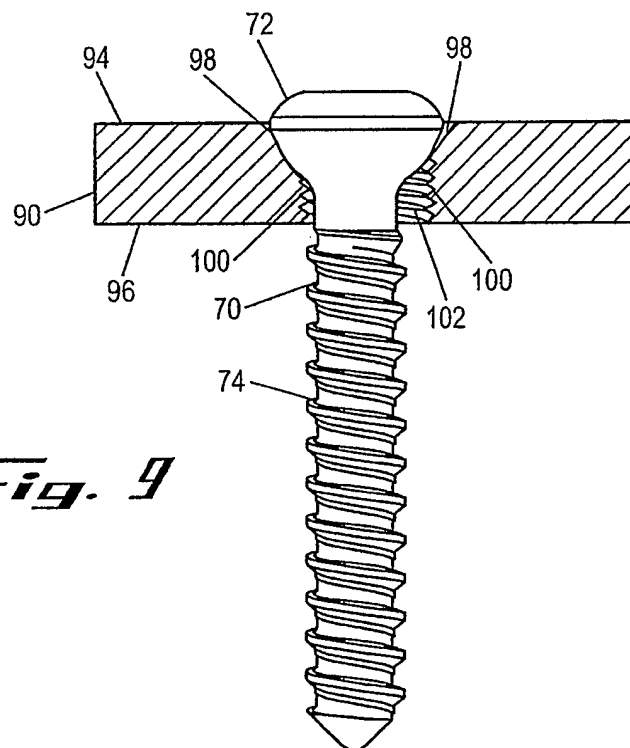
*Fig. 7B*



7/17

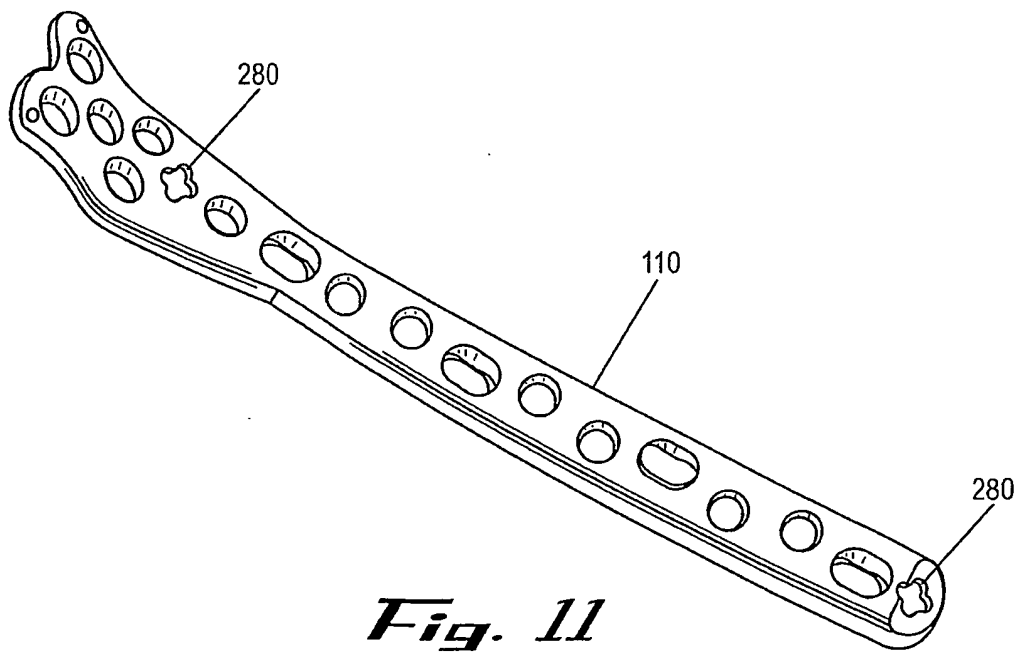
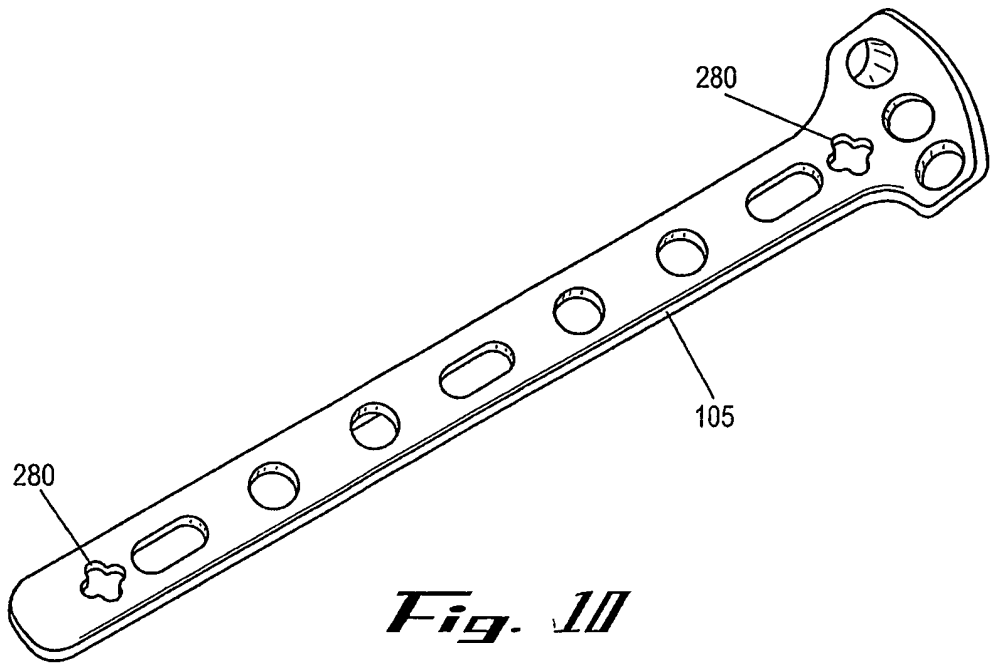


*Fig. 8*

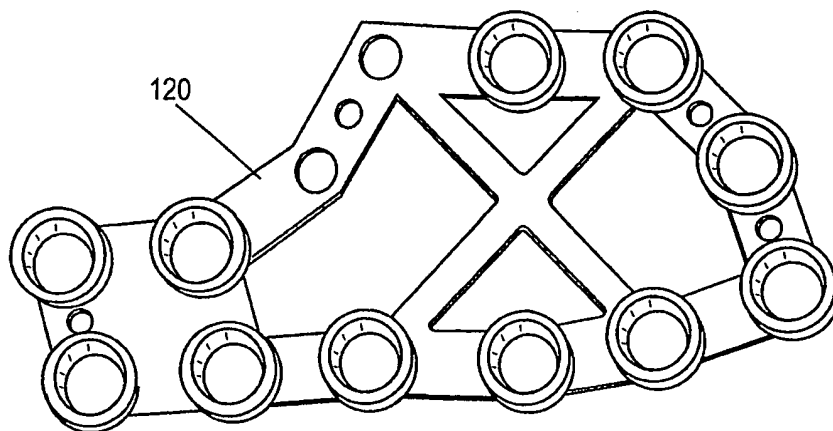


*Fig. 9*

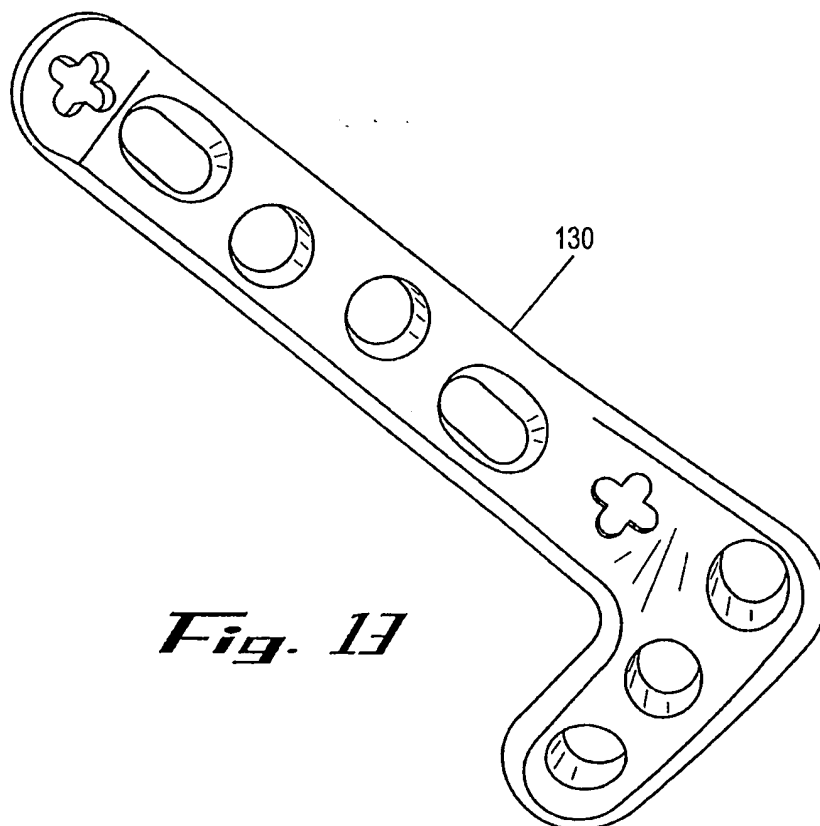
8/17



9/17

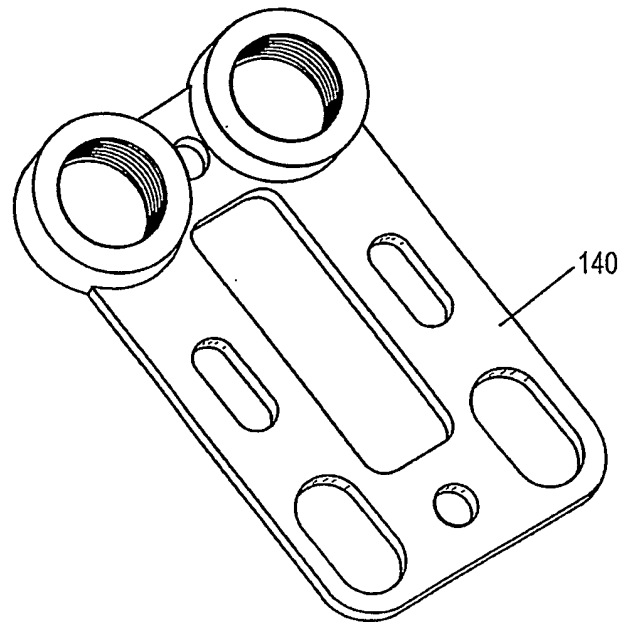


*Fig. 12*

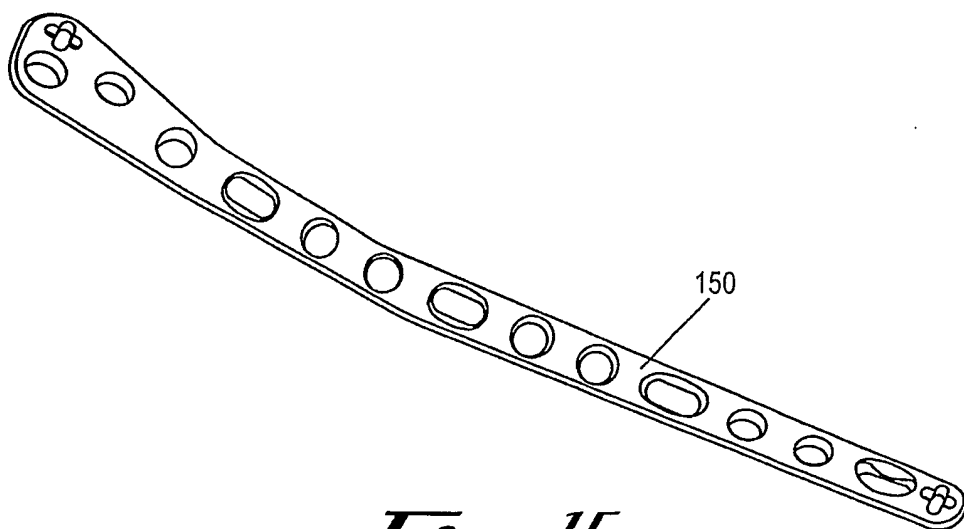


*Fig. 13*

10/17

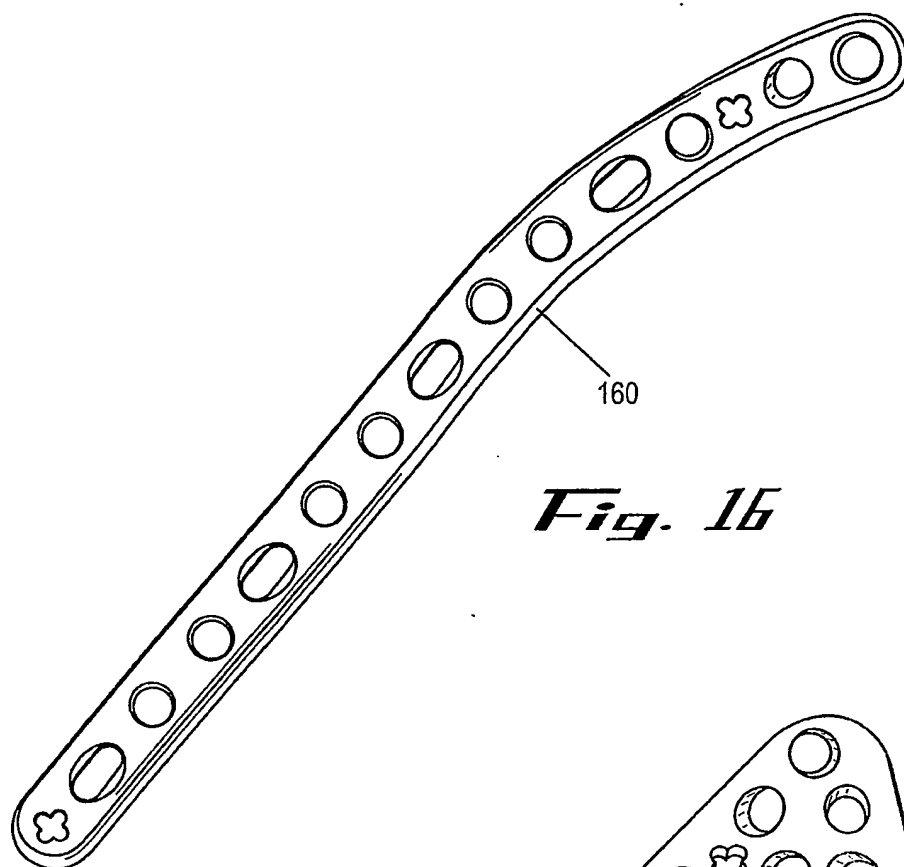


*Fig. 14*

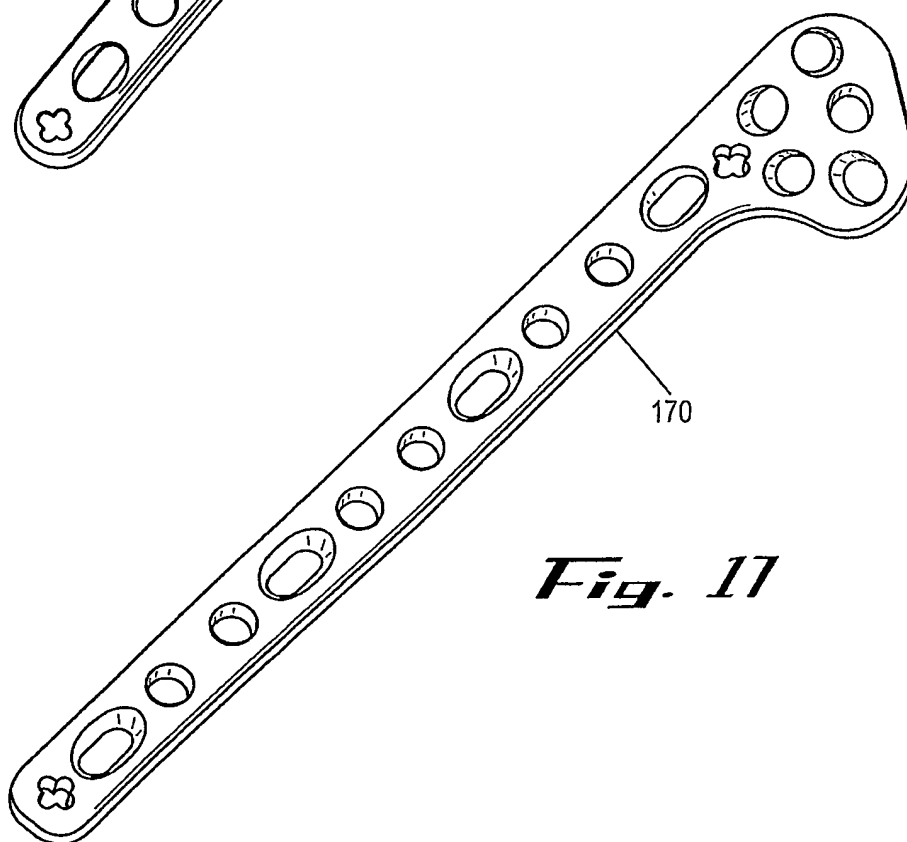


*Fig. 15*

11/17

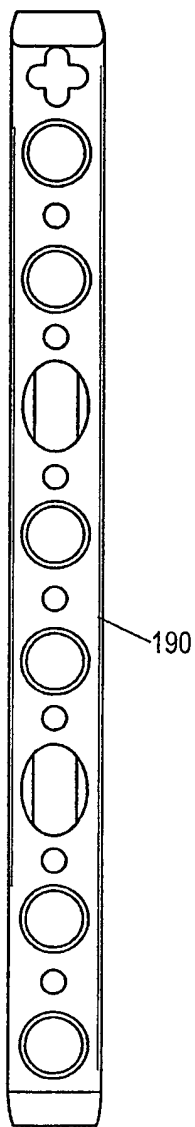
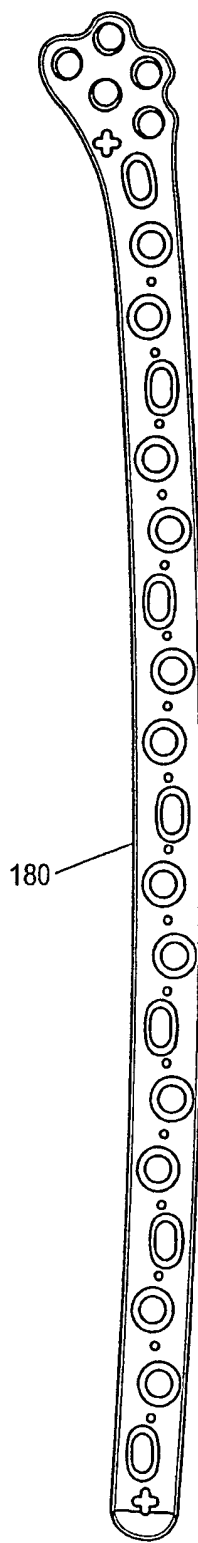


***Fig. 16***

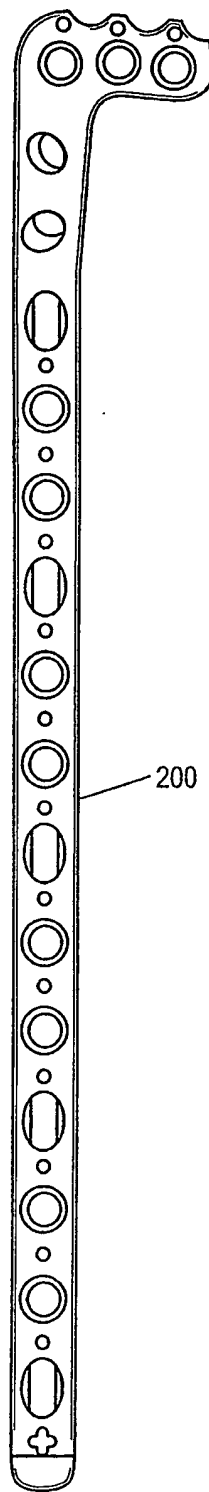


***Fig. 17***

12/17



*Fig. 19*

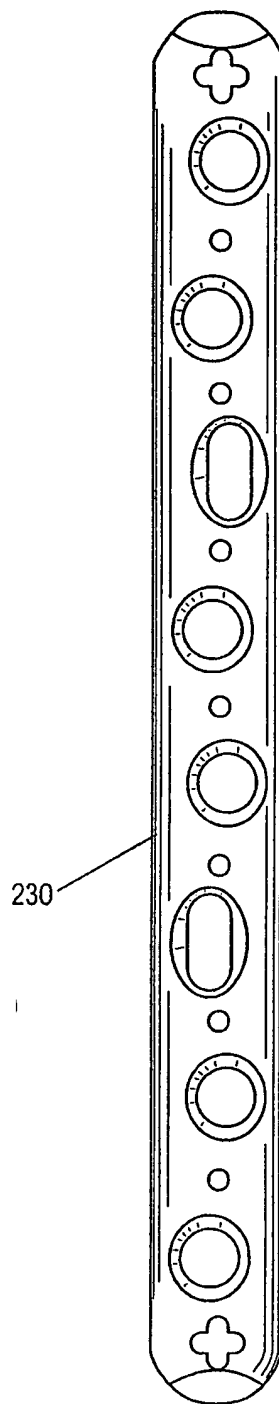
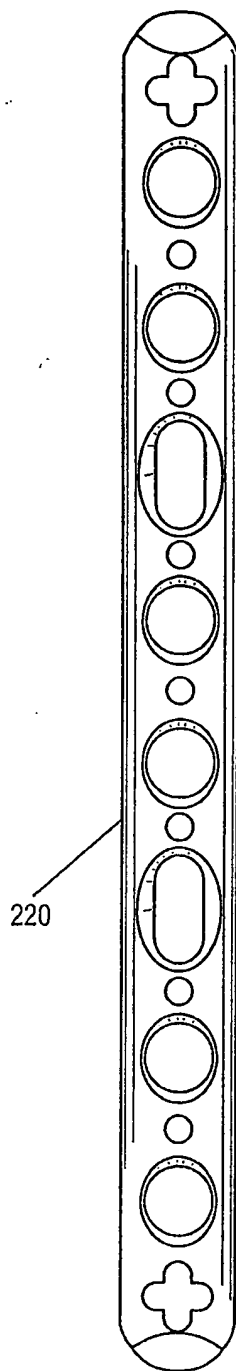
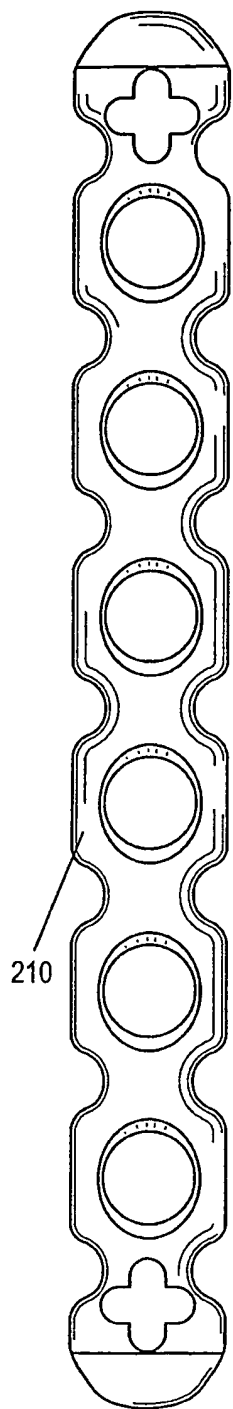


*Fig. 18*

*Fig. 20*



13/17

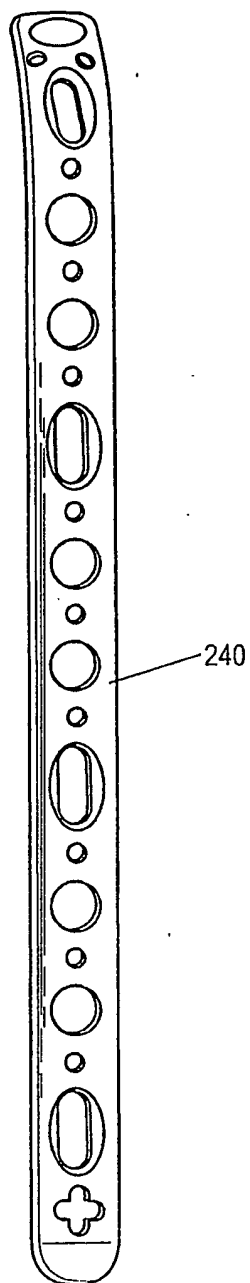


**Fig. 21**

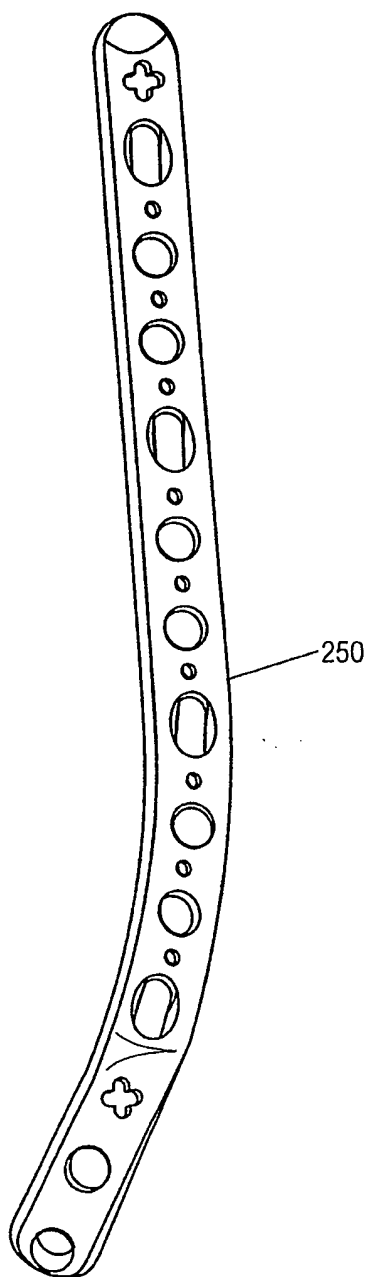
**Fig. 22**

**Fig. 23**

14/17

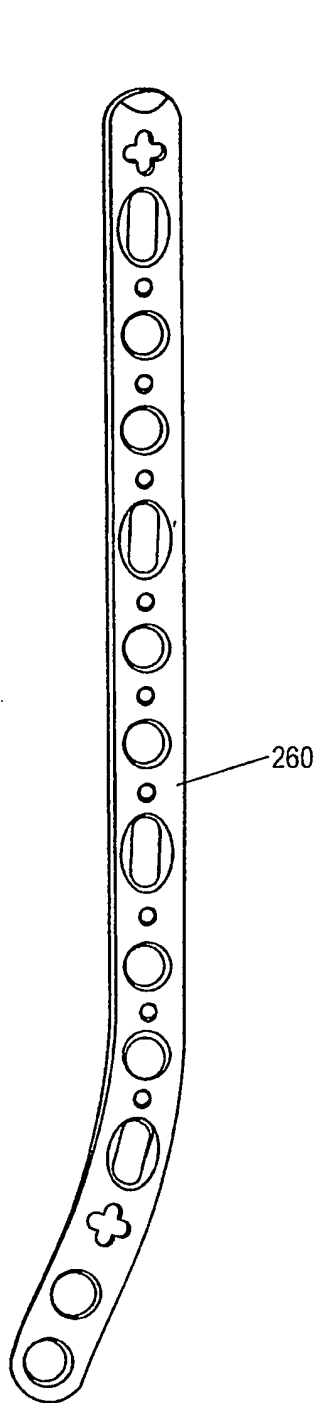


*Fig. 24*

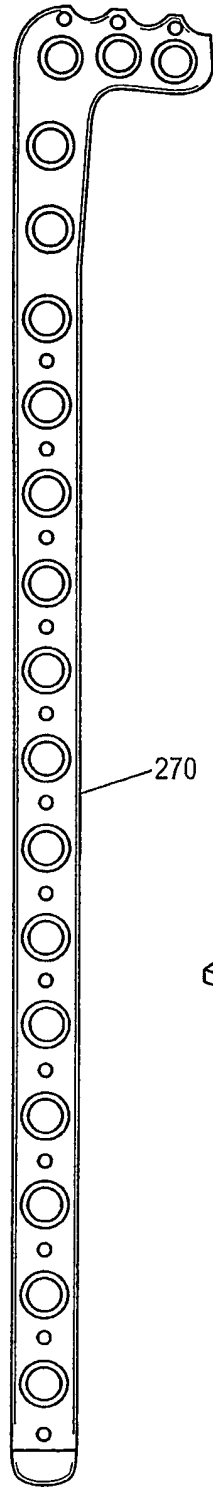


*Fig. 25*

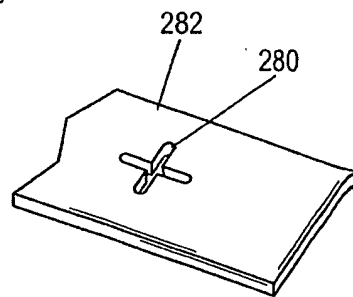
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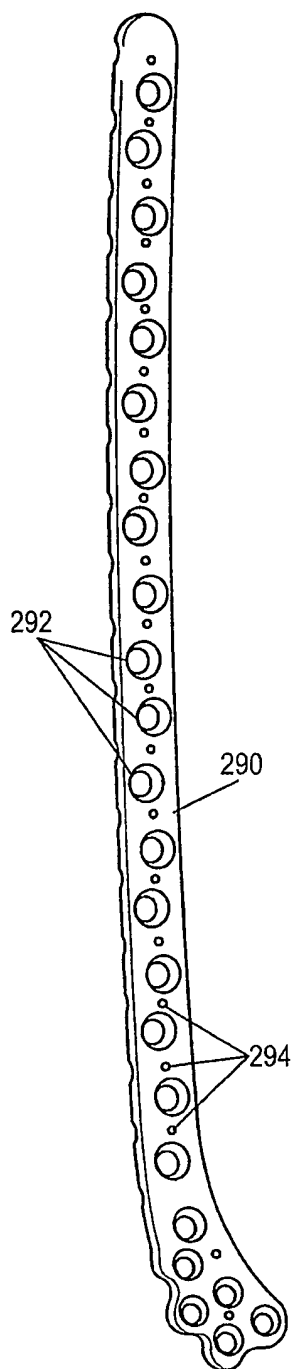
*Fig. 26*



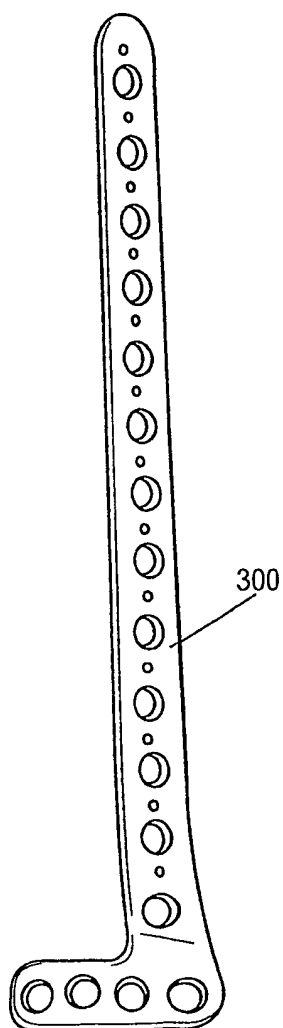
*Fig. 27*



*Fig. 28*

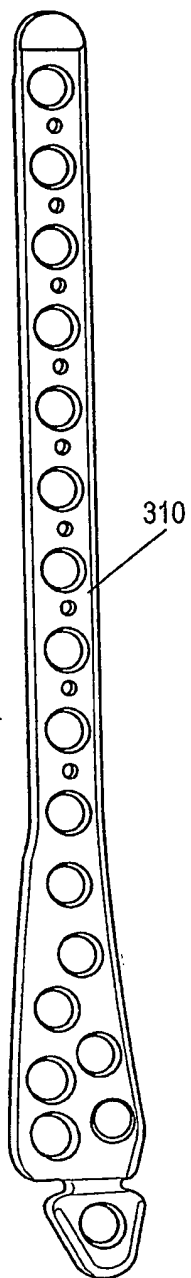


**Fig. 29**

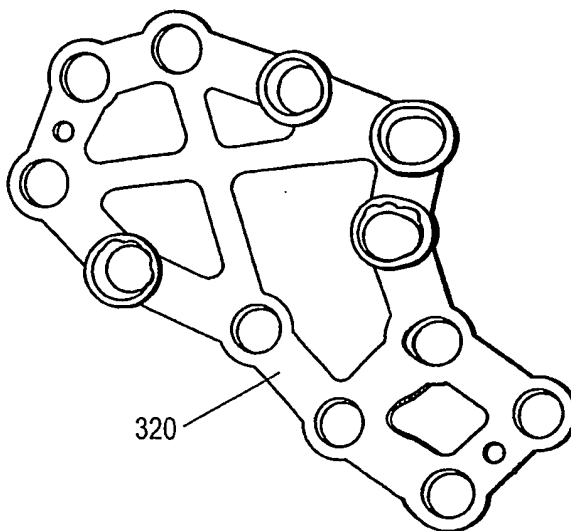


**Fig. 30**

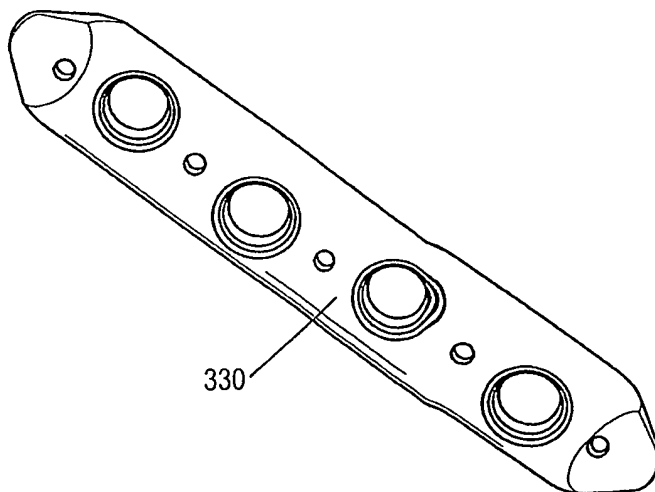
17/17



*Fig. 31*



*Fig. 32*



*Fig. 33*

# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/US2004/031653

**A. CLASSIFICATION OF SUBJECT MATTER**  
IPC 7 A61B17/80

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category * | Citation of document, with indication, where appropriate, of the relevant passages   | Relevant to claim No.                          |
|------------|--|--|
| X<br><br>A | <p>WO 01/19267 A1 (SYNTHES AG CHUR; SYNTHES ;<br/>WEAVER, PAUL, C; MAST, JEFF, W; MAYO,<br/>KEITH) 22 March 2001 (2001-03-22)<br/>abstract; figures</p> <p>page 1, paragraph 1<br/>page 3, paragraph 2 - page 4, paragraph 1<br/>page 6, line 14 - page 8, line 31<br/>page 10, lines 4-18</p> <p style="text-align: center;">-----<br/>-/--</p> | <p>1-4,<br/>6-10,12</p> <p>5,11,<br/>13-16</p> |

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

\* Special categories of cited documents :

- \*A\* document defining the general state of the art which is not considered to be of particular relevance
- \*E\* earlier document but published on or after the international filing date
- \*L\* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- \*O\* document referring to an oral disclosure, use, exhibition or other means
- \*P\* document published prior to the international filing date but later than the priority date claimed

- \*T\* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
- \*X\* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
- \*Y\* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.
- \*G\* document member of the same patent family

Date of the actual completion of the international search

1 February 2005

Date of mailing of the international search report

10/02/2005

Name and mailing address of the ISA

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Fax: (+31-70) 340-3016

Authorized officer

Lager, J

# INTERNATIONAL SEARCH REPORT

national Application No  
rCT/US2004/031653

| C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT |  |                       |
|--|--|-----------------------|
| Category *   | Citation of document, with indication, where appropriate, of the relevant passages   | Relevant to claim No. |
| X  | DE 43 43 117 A1 (WOLTER, DIETMAR,<br>PROF.DR., 20099 HAMBURG, DE; WOLTER,<br>DIETMAR) 22 June 1995 (1995-06-22)  | 1-3,6,7,<br>10        |
| A  | abstract; figures<br><br>column 1, line 55 - column 2, line 36<br>column 3, lines 32-57<br>column 4, lines 20-51<br>column 5, lines 6-29<br>-----                                  | 4,5,8,9,<br>11-16     |
| X  | US 6 206 881 B1 (FRIGG ROBERT ET AL)<br>27 March 2001 (2001-03-27)   | 1-3                   |
| A  | abstract; figures<br>column 1, line 18 - column 2, line 36<br>-----  | 4-16                  |
| A  | US 2002/045901 A1 (WAGNER MICHAEL ET AL)<br>18 April 2002 (2002-04-18)<br>abstract; figures<br>paragraph '0006! - paragraph '0018!<br>paragraph '0028! - paragraph '0031!<br>----- | 1-16                  |

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US2004/031653

## Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 17-19  
because they relate to subject matter not required to be searched by this Authority, namely:  
Rule 39.1(iv) PCT - Method for treatment of the human or animal body by surgery
2. ☐ Claims Nos.:  
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☐ No protest accompanied the payment of additional search fees.



# INTERNATIONAL SEARCH REPORT

Information on patent family members

national Application No

CT/US2004/031653

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s)  | Publication<br>date      |
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